UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

STATIONARY SPRAY PLANTS IN CALIFORNIA

(A Progress Report)

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In co-operation with T. A. WOOD, of the California Committee on the Relation of Electricity to Agriculture

BULLETIN 406

OCTOBER, 1926

UNIVERSITY OF CALIFORNIA PRINTING OFFICE
BERKELEY, CALIFORNIA
1926

FOREWORD

This bulletin is a contribution of the Divisions of Agricultural Engineering and Pomology and the Stationary Spraying Sub-Committee of the California Committee on the Relation of Electricity to Agriculture. It is the first of a series planned to report the results of investigations conducted jointly by the Agricultural Experiment Station, College of Agriculture, University of California, and the California Committee on the Relation of Electricity to Agriculture. This committee represents the agricultural and electrical industries in California that are working together for the purpose of making available reliable information concerning the use of electricity on the farm, and coöperating with similar committees in other states.*

E. D. Merrill,
Director, California Agricultural
Experiment Station.

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STATIONARY SPRAY PLANTS IN CALIFORNIA[1]

B. D. MOSES[2] AND W. P. DURUZ,[3] IN COÖPERATION WITH T. A. WOOD[4]

A stationary spray plant, as the name would imply, is an outfit that remains in a fixed place. The plant consists essentially of a power unit and pump of sufficient capacity to force spray liquids through underground pipes to all parts of the orchard. At convenient points lengths of hose are attached to the pipes and the spray material is applied to the trees in the usual way through spray rods or spray guns.

The prevailing method of spraying orchards has been, and still is, by means of movable sprayers. The common type consists of a tank, gasoline engine and pump mounted on wheels and drawn through the orchard by a team or tractor. A smaller outfit operated by man power may be hauled on a sled or wagon, and a still smaller unit may be operated by hand while the operator carries the load on his back.

Nowhere, perhaps, has the combating of diseases and insects affecting fruit trees been a more serious problem than in California, where the mild climate favors the overwintering of many pests. The wholesale planting of orchards during the last two decades, in many instances by persons unfamiliar with known cultural practices, has tended to aggravate the situation. New insects and new diseases have been introduced from other states and countries. Methods of combating pests in one locality or district have been found inapplicable to other districts with different climatic conditions.

The earlier deciduous orchards were planted along the coast and in coastal valleys. Later plantings followed the rivers farther inland. As an industry, fruit growing soon spread into the interior valleys and the adjacent foothills or wherever water was available for

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[1] The writers are indebted to the following fruit growers who have generously coöperated and permitted the study and testing of their stationary spray plants: Alfred G. Brown, Santa Clara; E. A. Gammon, Hood; L. B. Landsborough, with the A. B. Humphrey Ranch, Mayhews; W. W. Monroe, Sebastopol; Hayward Reed, Broderick; Howard Reed, Marysville, and Adrian C. Wilcox, Santa Clara.

[2] Division of Agricultural Engineering.

[3] Division of Pomology.

[4] California Committee on the Relation of Electricity to Agriculture.

irrigation. Soon many new problems in spraying had to be met and all existing knowledge of older districts in the eastern states and even in European countries was drawn upon, but in the end our experimenters had to work out their own spraying programs, often embracing new methods, new equipment, and even new materials.

The development of spraying equipment has gone forward slowly and conservatively. Eastern manufacturers, in the main, have kept step with the western manufacturers of spraying equipment, particularly as regards the portable gasoline power outfits. However, it remained for the western coast to devise and put into operation a new idea in spraying, namely, the stationary spray plant. Users of portable sprayers have often had some difficulty in spraying at exactly the proper time on account of muddy ground in the orchard. The ordinary portable spraying outfit, loaded with 200 gallons of liquid, weighs at least a ton. Obviously, such a load cannot be easily transported through an orchard just after a heavy rain or after a thaw.

A still greater difficulty in spraying arose in certain California orchards in the lowlands adjacent to the Sacramento River, which at certain times in the winter and early spring were apt to be inundated. Prune and pear orchards along the river were sometimes submerged to a depth of several feet for a week at a time. Owing to the sandy nature of the subsoil, no damage resulted to the trees themselves from the submergence, but while the water was on the ground and for several days afterward, it was impossible to spray. Unfortunately, one of the most vital spray applications for pears was necessary at a time when it was utterly impossible to enter the orchard with any sort of movable outfit. One orchard owner, Mr. Hayward Reed,[5] tried the plan of mounting a sprayer on a barge. He later used very long lengths of hose and even pipe-lines in order to spray considerable

[5] "The year 1906 was a disastrous one for me," writes Mr. Reed. "The scab infection was so bad that 98 per cent of the crop were No. 2 and No. 3 pears. Improper spraying was the cause. The following year, 1907, was my most successful season. High grade pears with other favorable conditions made this possible. As the time neared for scab spraying, a great flood came (fig. 1). I sprayed in boats while I could, but when the water receded some, this could not be done. Wagons also were of no avail. In a quandary I told Honda (my foreman) to couple the hose lengths together and spray as far as possible. We kept on until a thousand feet were used. At that time I conceived the idea of using pipes. Knowing how much cheaper and stronger they were, I felt they could carry the spray material long distances, and that hose attached at different intervals would operate successfully. The following year, 1908, I installed the underground pipe system at Rose Orchard, using ¾-inch pipe for main and laterals. Since then I have enlarged the system, using 1½-inch for main and ¾-inch for laterals. The year 1909 proved the value of the pipe system. Another great flood came. Our spraying was done on time by men working in gum boots. Later I installed the system in the New England, Folsom, and Gridley orchards."

areas from high ground. This finally gave him the idea of establishing a central pumping plant and carrying pipes underground from it to all parts of the orchard. At intervals there were risers located close to the trees so they would be out of the way, where spray hoses could be attached. After much experimenting, the number of trees

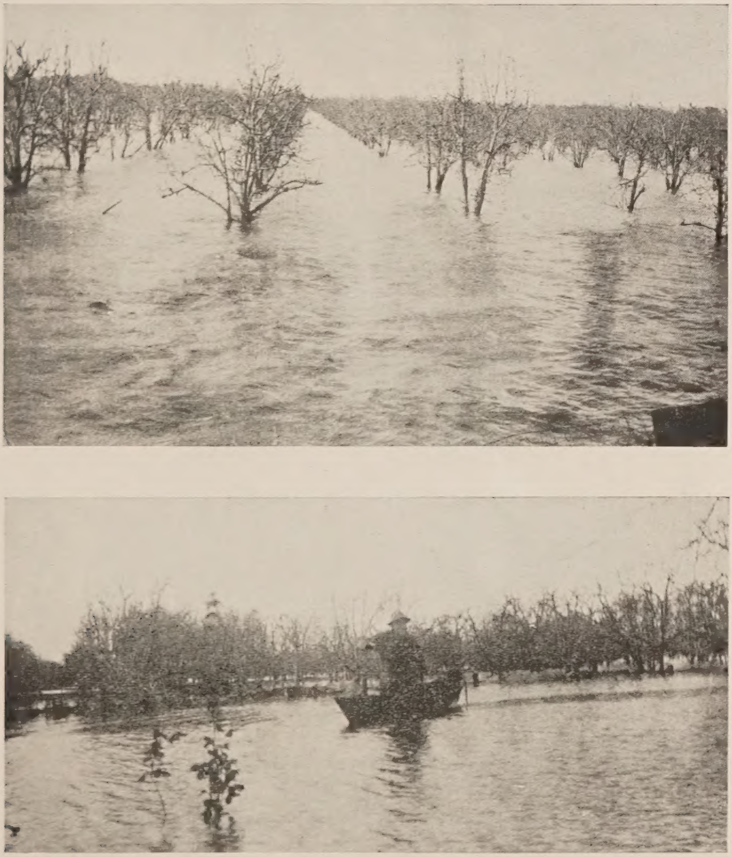


Fig. 1.—Flood scenes in 1906 in the Hayward Reed orchard.

possible to be sprayed economically from one point was found. Many other details, such as size of pipes for mains and laterals, and the required capacity of the pump were worked out.

Mr. Reed's system proved so satisfactory that other fruit growers have installed similar plants. A survey made in 1925 revealed at least

ten stationary plants in successful operation in California. The state of Washington[6] has several hundred plants. Most of these are located in the Wenatchee and Yakima districts. In that state conditions making it difficult to spray at the right times by old methods have brought about this extensive use of the stationary outfits.

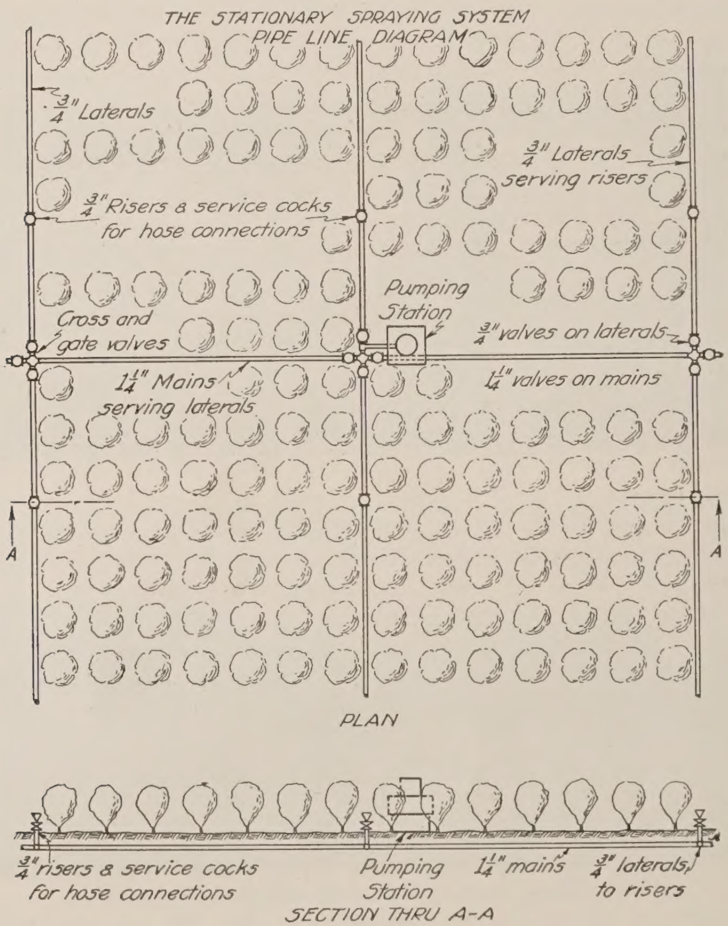


Fig. 2.—Diagram of stationary spraying system.

[6] Morris, O. M., Stationary spray plants, Wash. Agr. Exp. Sta. Popular Bul. 125:1–20. 1924.

GENERAL DESCRIPTION

Figure 2 shows diagrammatically the general arrangement of the underground pipes in a stationary spray system. The location of the pumping station is governed by the size of the orchard, water supply, power lines, roads, ranch buildings, and the topography of the land. It is usually near the center of the orchard. The equipment of the pumping station consists of a heavy duty spray pump driven by an

Fig. 3.—Pumping station of the two-story type. The lower floor is used for the service tank, pump, and motor, while the upper floor is for mixing the materials. The auxiliary water tank is a recommended accessory in order to insure plenty of water when needed.

electric motor or a gas engine and provided with mixing and service tanks. The equipment used on portable rigs may be employed in the stationary plant, but provision must be made for any increase in pressure or discharge.

A main line is laid from the pump through the center or along one side of the orchard with laterals leading off from it. Outlets are systematically provided on laterals so that hose may be attached for spraying the trees. All permanent piping is laid about eighteen inches below the surface of the ground so as not to interfere with tillage.

DESCRIPTION OF SEPARATE UNITS

Housing.—The pumping equipment should be housed in a suitable building, the type depending upon whether it is to be used solely for housing spray machinery and materials or for other purposes as well. Figure 3 shows a type of building which is used for spraying only; figure 4, the interior of a building used for spraying, for storage, and for housing an irrigation pump, and figure 5, a building which is used as a farm shop as well as for storage. The main essential is to have the building so arranged as to facilitate the handling of spray materials.

Power Unit.—The power unit consists of either an electric motor or a gas engine and the power is transmitted to the pump by belt, gears, or chain (fig. 6). Any standard electric motor may be used, ranging from 5 to 15 horsepower, according to the size of the pump and the pressure to be maintained. If a belt drive is used, the motor should be connected to the pump with a belt of correct length to prevent "belt slap," using pulleys of proper sizes to obtain the speed specified for the pump.

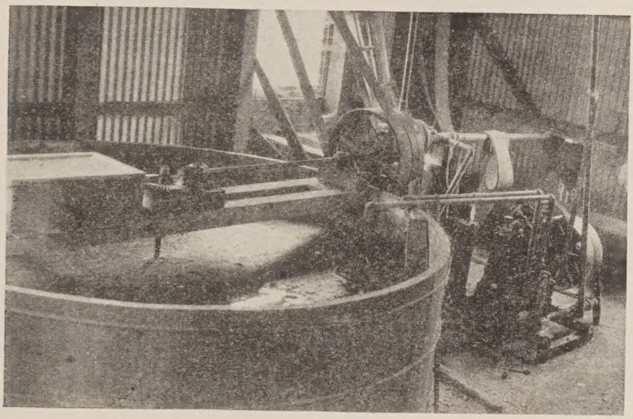
For an electric installation, the line from the transformer to the motor should not be excessively long and wire of the proper size should be used to avoid excessive voltage drop. The motor base, starter box, and switch box should, of course, be grounded. This precaution is especially important since the floor of the pump house is usually wet.

If a gas engine is used, it should be equipped with a reliable governor in order to avoid damage from excessive engine speeds.

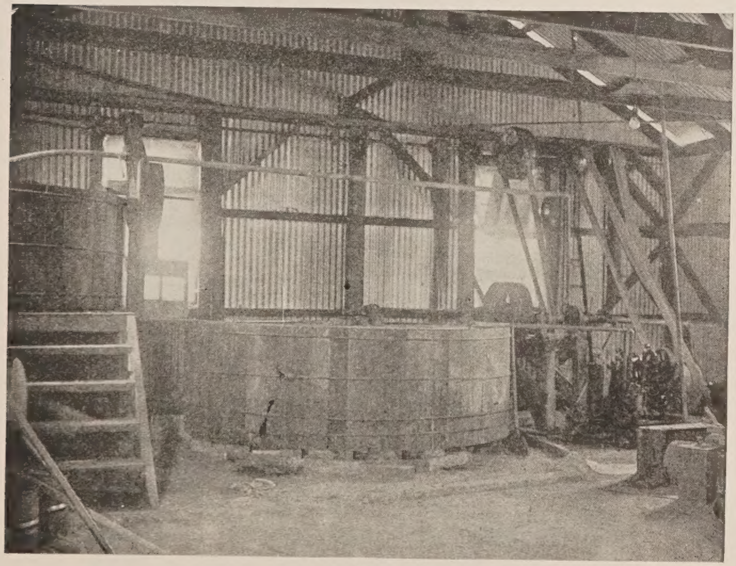
Pump.—A heavy duty pump is necessary to develop high pressures at the nozzles. In long lines of pipe, where several nozzles are used and velocities through the pipe are relatively high, pump pressures as great as 400 pounds to the square inch are necessary. In short lines of pipe, pump pressures vary from 250 to 300 pounds to the square inch. Because of the heavy duty performed by it, the pump must be placed on a solid base, preferably concrete.

Tanks.—Two round-bottomed wooden tanks, similar to those on portable rigs, are commonly used, both for mixing the liquid and serving the pump. Such tanks range in size from 200 to 1000 gallons each. Two systems of arrangement are followed: in one, a small mixing tank is on a higher level than the larger service tank, and in the other, both tanks are of the same size and on the same level. In the first arrangement the service tank is replenished from the mixing tank (figs. 3 and 4), while in the second the tanks are alternately used for mixing and service by transferring the suction hose or by operating a two-way valve on the pump suction (fig. 7).

Each tank is fitted with its own agitator driven from the pump shaft. In some instances the agitator of the mixing tank is horizontal and is driven from the tail-end of the agitator shaft of the service tank. In other cases the agitator is vertical and is driven by a shaft



a



b

Fig. 4.—Interior of pumping station.

a. Shows service tank with vertical agitator.

b. Shows mixing tank, service tank, and pump. Belts connect with a 35-h.p. electric motor which is also used for pumping water for irrigation.

Fig. 5.—A well-planned pumping station which has many conveniences. The mixing of spray materials is facilitated by a vat in the ground, into which the lime-sulfur is poured from the barrels and then pumped by means of a hand pump to the mixing tank. The brick furnace is used in heating water for oil emulsions. The far end of this building is used as a farm shop and for storage. The photograph shows an auxiliary portable sprayer being filled from the same mixing tank that is used for the stationary system.

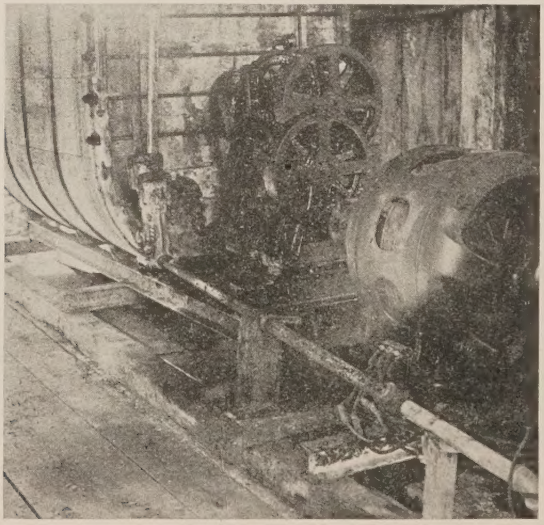


Fig. 6.—A typical installation showing mixing tank, pump, and power unit. A 10-hp. electric motor is used for driving the pump.

and gears from the power unit. Vertical agitators in flat-bottomed tanks (fig. 4) require special attention because of the tendency of the mixture, as a whole, to whirl, causing heavy materials in suspension to settle along the sides and bottom. This objection is not found with horizontal agitators in the round-bottomed tanks.

An adequate supply of water should be piped to the tanks, either from a reservoir, tank, or pump, as shown in figures 3 and 5.

Pipe Lines.—After a careful study of the orchard topography and tree spacing, a piping diagram should be drawn and the trenches dug accordingly (fig. 8). Galvanized iron pipe with screw fittings should

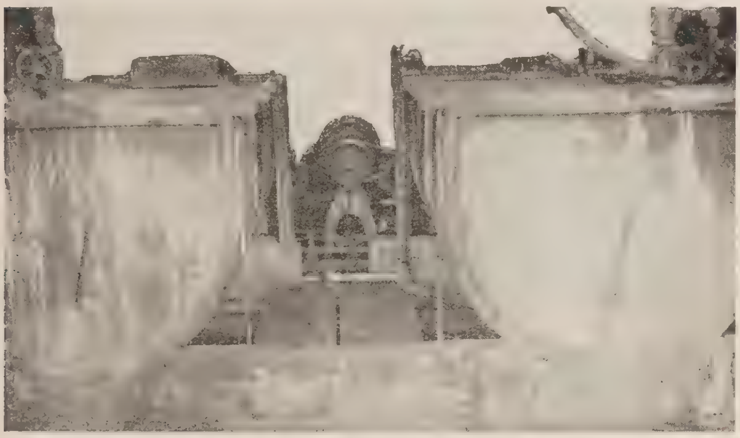
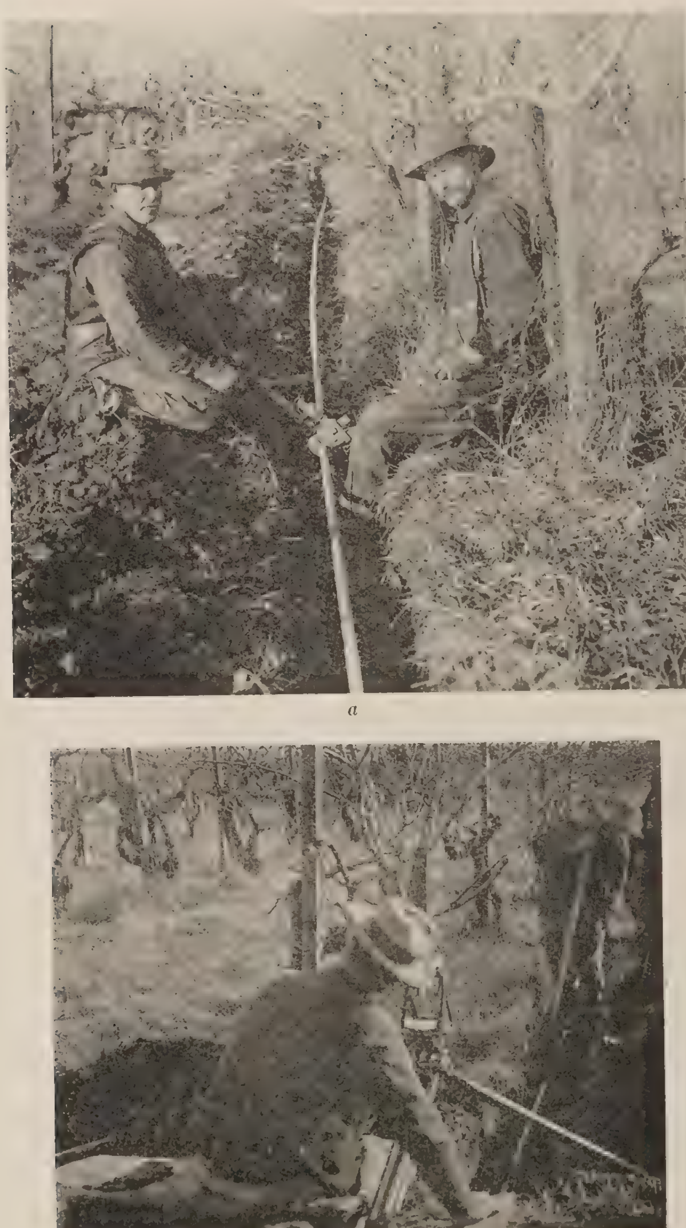


Fig. 7.—This illustrates two tanks on the same level. Each in turn serves as a mixing tank and a service tank.

be selected to stand the pressure under which it is to operate (see table 1). The pipe lines consist of mains, 1 to 1½ inches in diameter, and laterals ¾ to 1 inch in diameter, with gate valves between the pump and the mains and at the head of each lateral (fig. 9). This arrangement facilitates flushing the line and also aids in preventing the settling of spray material in laterals not being used. Frequent use of unions is recommended so as to simplify future repairs or alterations in the line. Because of the high pressures to be maintained, good pipe-compound must be used in making connections, and the pipe and fittings must be screwed tight. Abrupt turns in the line should be avoided wherever possible. Long radius bends are better than ordinary short elbows. All pipe should be carefully reamed so as to eliminate constrictions from cutting or threading. These precautions will reduce friction losses and permit high nozzle pressures. Table 2 gives the friction loss per thousand feet for ordinary and for old iron pipe.



a

b

Fig. 8.

a. Connecting pipe before lowering into the trench.
b. Laying the pipe to an even grade by means of a level before covering.

It is a customary practice to place a lateral at every eighth row of trees and a riser or service connection at every fifth tree in the row. This may be modified for different orchards, according to the planting distance, but in any case the risers should be not more than 150 or 160 feet apart to avoid hose lengths of more than 100 feet.

Figure 10 shows the location of risers in different orchards. If they are permanent, the risers should be protected by posts or should be located near trees; temporary risers should be removed after each spraying period, the fittings for the connection being located at the

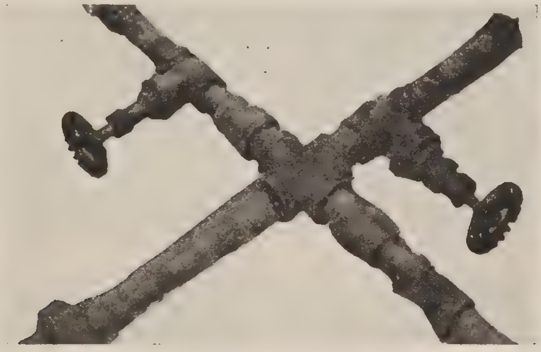


Fig. 9.—Gate valves on the main and lateral should be provided.

TABLE 1

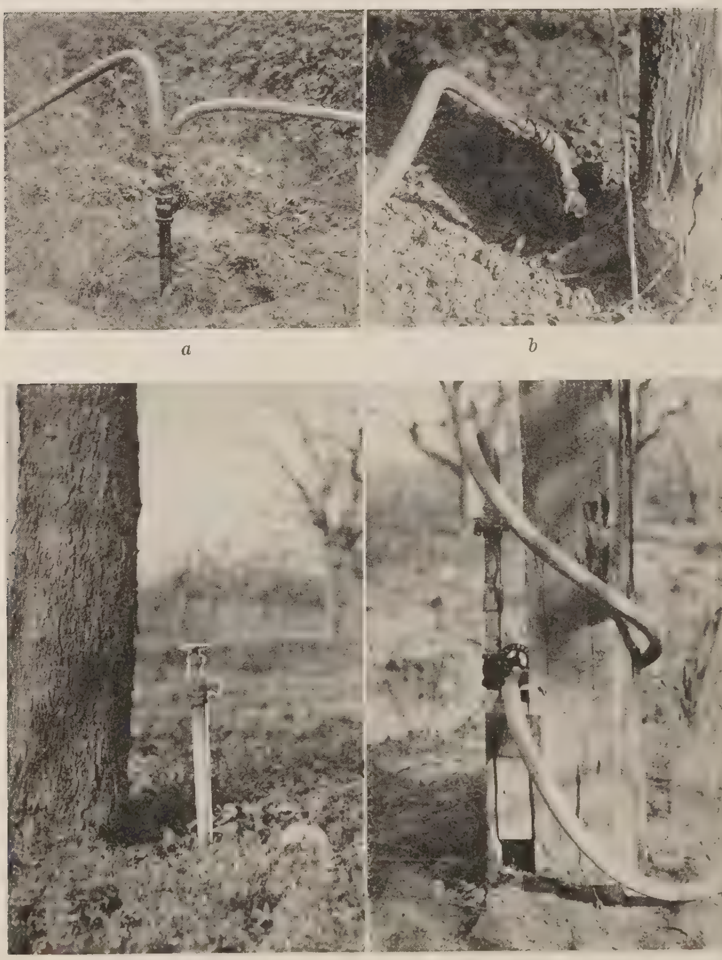
STRENGTH OF NEW BUTT-WELDED WROUGHT STEEL PIPE IN POUNDS PER SQUARE INCH*

Size, inches	Standard		Extra strong		Double extra strong	
	Bursting pressure, Barlow's formula	Working pressure	Bursting pressure, Barlow's formula	Working pressure	Bursting pressure, Barlow's formula	Working pressure
½	10,384	1298	14,000	1750	28,000	3,500
¾	8,608	1076	11,728	1716	23,464	2,933
1	8,088	1011	10,888	1611	21,776	2,722
1¼	6,744	843	9,200	1150	18,408	2,301
1½	6,104	763	8,416	1052	16,840	2,105
2	5,184	648	7,336	917	14,680	1,835
2½	5,648	706	7,680	960	15,360	1,920
3	4,936	617	6,856	857	13,714	1,714

* NOTE.—After Crane Company Catalogue 50 : 626. 1917. The safe working pressure varies from 617 pounds per square inch in the three-inch pipe to 1298 pounds per square inch in the ½-inch pipe, all of which are higher than the pressures likely to be obtained at any time in the piping systems. Since standard fittings and valves do not carry quite as high pressures as the standard pipe, it may be better to use heavy valves, especially in the larger sizes.

intersection of diagonals between trees. Each riser is fitted with a service cock and a hose coupling.

Hose.—The best quality high pressure rubber hose must be used in order to withstand the heavy pressure and hard service to which it is subjected when dragged through the orchard. The size is usually $\frac{7}{16}$-inch and the length should not be over 100 feet (fig. 11).



a *b*

c *d*

Fig. 10.—Four types of risers.

a. Double gate valve.
b. Service cock.
c. Garden valve.
d. Gate valve.

a

b

Fig. 11.—Spraying by means of the stationary system.

a. Using spray rod with 200 feet of hose. A helper is necessary to assist in moving the hose about.

b. Using the spray gun with 74 feet of hose. One man can handle this length satisfactorily.

TABLE 2

FRICTION DROP IN PIPES FOR VARIOUS RATES OF DISCHARGE*

Dis-charge gal. per min.	½ in. Wrought iron pipe, actual inside diameter .623 in.			¾ in. Wrought iron pipe, actual inside diameter .824 in.			1 in. Wrought iron pipe, actual inside diameter 1.048 in.		
	Velocity in ft. per sec.	Pressure drop per 1000 ft. of pipe in lbs.		Velocity in ft. per sec.	Pressure drop per 1000 ft. of pipe in lbs.		Velocity in ft. per sec.	Pressure drop per 1000 ft. of pipe in lbs.	
		Ordinary iron	Old iron		Ordinary iron	Old iron		Ordinary iron	Old iron
1	1.05	9.1	13.45	......	......	......	......	......	......
2	2.10	32.2	48.6	1.20	8.24	12.58	......	......	......
3	3.16	68.5	104.2	1.80	17.78	26.45	1.12	5.47	8.24
4	4.21	117.3	177.8	2.41	30.35	46.05	1.49	9.28	14.01
5	5.26	177.8	268.8	3.01	46.05	68.9	1.86	14.09	21.29
6	6.31	247.2	377.3	3.61	63.7	97.1	2.23	19.73	29.92
7	7.37	329.5	498.5	......	......	......	......	......	......
8	8.42	425.0	642.	4.81	108.4	164.8	2.98	33.82	50.7
9	9.47	525.0	793.5	......	......	......	......	......	......
10	10.52	637.5	967.0	6.02	164.8	253.0	3.72	50.7	76.8
12	......	......	......	7.22	229.8	343.5	4.46	71.1	108.4
14	......	......	......	......	......	......	5.20	95.4	143.2
15	......	......	......	9.02	343.5	529.0	......	......	......
16	......	......	......	......	......	......	5.95	121.4	182.2
18	......	......	......	......	......	......	6.69	151.8	225.5
20	......	......	......	12.03	589.5	893.0	7.44	182.2	277.5
22	......	......	......	......	......	......	......	......	......
24	......	......	......	......	......	......	......	......	......
25	......	......	......	......	......	......	9.30	277.5	416.3
26	......	......	......	......	......	......	......	......	......
28	......	......	......	......	......	......	......	......	......
30	......	......	......	......	......	......	11.15	385.8	585.
35	......	......	......	......	......	......	13.02	516.	781.
40	......	......	......	......	......	......	14.88	659.	998.
45	......	......	......	......	......	......	......	......	......
50	......	......	......	......	......	......	......	......	......

* Adapted from Williams and Hazen, Hydraulic Tables, 3rd edition, pp. 26–29, 1920. Publisher—John Wiley & Sons, Inc., New York.

TABLE 2—(*Concluded*)

Friction Drop in Pipes for Various Rates of Discharge*

Discharge gal. per min.	1¼ in. Wrought iron pipe, actual inside diameter 1.380 in.			1½ in. Wrought iron pipe, actual inside diameter 1.611 in.			2 in. Pipe or hose, actual inside diameter 2.00 in.		
	Velocity in ft. per sec.	Pressure drop per 1000 ft. of pipe in lbs.		Velocity in ft. per sec.	Pressure drop per 1000 ft. of pipe in lbs.		Velocity in ft. per sec.	Pressure drop per 1000 ft. of pipe or hose in lbs.	
		Ordinary iron	Old iron		Ordinary iron	Old iron		Ordinary	Old
1	......	......	......	......	......	......	......	......	......
2	......	......	......	......	......	......	......	......	......
3	......	......	......	......	......	......	......	......	......
4	.86	2.47	3.73	.63	1.137	1.735	......	......	......
5	1.07	3.64	5.51	.79	1.726	2.602	......	......	......
6	1.29	5.20	7.89	.94	2.428	3.642	.61	.868	1.258
7	1.50	6.90	10.41	1.10	3.208	4.355	......	......	......
8	1.72	8.81	13.45	1.26	4.12	6.20	.82	1.432	2.168
9	......	......	......	1.42	5.12	7.76	......	......	......
10	2.14	13.23	19.95	1.57	6.20	9.41	1.02	2.168	3.295
12	2.57	18.65	28.2	1.89	8.72	13.18	1.23	3.035	4.64
14	3.00	24.72	37.7	2.20	11.62	17.56	1.43	4.075	6.16
15	......	......	......	......	......	......	......	......	......
16	3.43	31.65	48.3	2.52	14.78	22.54	1.63	5.204	7.89
18	3.86	39.45	59.4	2.83	18.39	27.74	1.84	6.46	9.84
20	4.29	48.3	72.9	3.15	22.55	33.82	2.04	7.89	11.93
22	......	......	......	3.46	26.88	40.32	......	......	......
24	......	......	......	3.78	31.65	46.82	......	......	......
25	5.36	72.0	108.8	......	......	......	2.55	11.84	18.04
26	......	......	......	4.09	36.42	55.07	......	......	......
28	......	......	......	4.41	42.06	63.3	......	......	......
30	6.43	101.8	155.2	4.72	47.68	71.98	3.06	16.65	25.15
35	7.51	135.3	207.5	5.51	63.75	95.4	3.57	22.12	33.82
40	8.58	173.5	264.5	6.30	81.5	121.8	4.08	28.62	42.92
45	......	......	......	7.08	100.6	151.8	4.60	35.55	53.3
50	10.72	260.1	398.8	7.87	123.2	185.6	5.11	42.92	65.05

* Adapted from Williams and Hazen, Hydraulic Tables, 3rd edition, pp. 26-29, 1920. Publisher—John Wiley & Sons, Inc., New York.

TABLE 3

DESCRIPTION OF STATIONARY SPRAY PLANTS

FIELD OBSERVATIONS

Test group	A			B	C	D			E	F
Test number	1*	7*	8*	2*	3*	4†	6†	10	5	9‡
Kind of trees	Pear	Pear	Pear	Pear	Pear	Pear	Pear	Pear	Pear	Pear
Size of orchard, acres	260	130	130	250	56½	50	50	50	56	30
Year installed	1907	1907	1907	1907	1909	1922	1922	1922	1923	1925
Pump location	Center	Center	Center	Center	Corner	Corner	Corner	Corner	Side	Corner
Number pump cylinders	4	3	4	3	3	3	3	3	3	3
Bore, inches	3¼	4	3¼	3¼	3¼	3¼	3¼	3¼	3	3
Size of motor, hp	7.5	7.5	7.5	10	35	10	10	10	5	15
Transformer distance, feet	2500	2000	2500	600	50	100	100	100	50	100
Size of wire, number	8	8	8	10	6	6	6	6	8	6
Number of trees	20200	10100	10100	22000	4300	5000	5000	5000	6400	2250
Tree spacings, feet	20x20	20x20	20x20	20x20	16x16	16x24	16x24	16x24	17x20	24x24
Age of trees, years	2 to 20	2 to 20	2 to 20	15 to 34	3 to 60	23	23	23	3 to 35	5 to 40
Size of main, inches	2	1	1	1½	1½	1	1	1	1	1¼
Location of main	Center	Center	Center	Center	Side	Side	Side	Side	Side	Side
Size of lateral, inches	¾	¾	¾	¾	¾ & 1	¾	¾	¾	¾	¾
Lateral spacings, feet	....	....	....	....	128	192	192	192	140	120
Take-off spaces, feet	....	....	....	....	80	80	80	80	140 &120	96
Hose length, feet	250	200	200	180	80	115	115	115	125	75
Initial cost	$15000	$7500	$7500	$10000	$6000	$1875	$1875	$1875	$1110	$1560

* Initial cost high due to repairs and fire. Any one of the systems can be installed at a far smaller figure.

† Starting compensator discovered to be grounded and power reading therefore is high.

‡ System designed for 150 acres—30 acres now piped.

Nos 5 and 9—use general utility motor. No. 3—uses irrigation motor, others use individual motors.

FIELD OBSERVATIONS

In order to obtain first-hand knowledge of the stationary spray systems as they are operated in California, the writers made a personal canvas of the state, locating six such installations and securing the coöperation of the owners. Three different methods for securing information were used: (1) field observations, (2) questionnaires to owners, and (3) field tests.

The results of this investigation are given in tabular form. Table 3 gives a physical description of the six orchards upon which ten separate tests were run. Table 4 gives the conditions under which the tests were run and the results obtained. Tables 5 and 6 have been compiled from the information furnished by the owners and from data secured during the tests.

Operation of the System.—At the beginning of the spraying period the pump and power unit are inspected, risers installed, if they are not already in place, and hose couplings attached. The foreman directs his men according to the plan of spraying to be followed. Helpers become necessary when long lengths of hose are used. Where risers are fitted with double service cocks, one helper can take care of two or more hose (fig. 10*a*). It is a good plan to distribute the hose throughout the orchard, using different laterals and thereby maintaining satisfactory nozzle pressures.

The pump is started and all lines are filled with water to prevent the subsequent filling of unused pipes with spray liquid. All valves are then closed including the cut-off cock at the pump. The spray mixture is prepared and the service tank filled (fig. 12).

Meanwhile the men in the orchard have connected their hose and opened the proper service cocks. When the mixture in the tank has been thoroughly agitated and sufficient pressure developed, the cut-off cock at the pump is opened, thus applying pressure to the piping system. As soon as the clear water has been expelled, spraying begins.

In the spraying operation each man with a hose adopts a definite system to prevent missing trees or portions of trees and to avoid winding the hose around trees already sprayed. Figure 13 shows a good system to follow. As spraying progresses, new laterals are turned on and the old ones shut off.

At the end of the day that part of the system which has been used is flushed out by pumping clear water through this part of the pipe-

a b c d

Fig. 12.—Showing methods by which concentrated lime-sulfur is conveyed to the mixing tank.

a. Dipping the concentrated solution from an underground reservoir and carrying it in buckets to the mixing tank. *b.* Using suction pump to lift solution from an underground reservoir to the mixing tank. *c.* A suction hose withdrawing the liquid directly from a barrel of the concentrated solution. *d.* Lifting a full barrel to the mixing platform.

line. Flushing is accomplished by changing the suction from the service tank to the water supply by means of cross valves, or by filling the service tank itself with water. Men on the last lateral continue spraying until clear water appears. The foreman determines when to turn in clear water in order to finish spraying before quitting time; flushing is thus completed soon after spraying is finished. Thorough flushing is especially important after spraying with materials such as arsenate of lead or Bordeaux mixture.

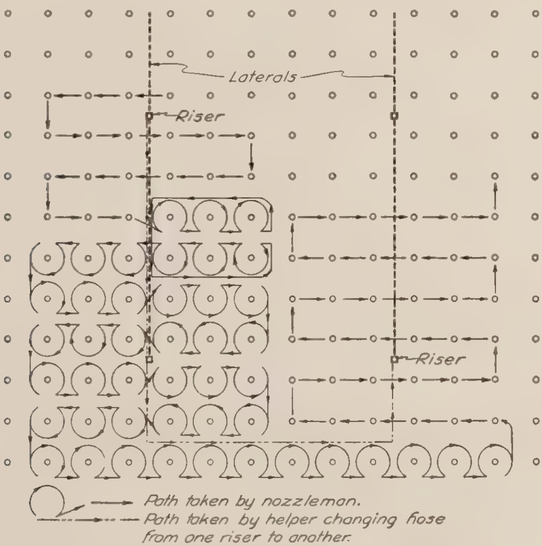


Fig. 13.—A plan for routing nozzle-man so that no trees will be missed.

The diagram is simply suggestive, the purpose being to illustrate how the nozzle-man can be routed so as not to miss any trees, and so as to prevent twisting and tangling of the hose. Three blocks are shown, the detail path for the last three trees only is shown in the upper left-hand block, to illustrate how the connection may be transferred from one riser to another. The first route in the lower right-hand block is shown in detail, to illustrate the method of transferring from one riser to another at the end of the lateral.

TABLE 4

RESULTS OF FIELD TESTS—1925

Test group	A			B	C	D			E	F
Test number	1*	7*	8*	2	3†	4‡	6‡	10	5	9§
Date tested	Feb. 26	Apr. 14	Apr. 15	Mar. 3	Mar. 4	Mar. 6	Apr. 9	May 7	Mar. 7	Apr. 28
Spray used‖	L. S.	A. of L.	A. of L.	L. S.	L. S.	L. S.	A. of L.	A. of L.	L. S.	A. of L.
Voltage—no load	223	223	223	223	257	235	238	244	235	252
Voltage—load	188	206	194	206	254	222	231	230	225	242
Voltage drop	35	17	29	17	3	13	7	14	10	10
Speed of motor r.p.m.	840	865	840	900	902	1197	1185	1202	1194	1203
Speed of pump r.p.m.	48	48	48	42	44	44	44	44	38	59
Pump pressure—lbs. per sq. in.	325	350	400	235	240	360	415	415	300	380
Length of main in use, feet	.....	None	None	1000	.....	1056	1100	960	347	.....
Length of lateral in use, feet	.....	560	2520	800	.....	836	200	1160	1080	.....
Riser pressure—lbs. per sq. in.	.....	305	325	.....	210	245	280	192	235	.....
Pressure drop to riser, lbs.	.....	45	75	.....	30	115	135	223	65	.....
Length of hose used, feet	250	200	200	180	80	115	115	115	125	75
Nozzle pressure—lbs. per sq. in.	.....	285	285	170	185	215	255	165	220	.....
Pressure drop in hose, lbs.	.....	20	40	.....	25	30	25	27	15	.....
Number of rods or guns in use	15 rods	8 rods	8 rods	12 rods	6 guns	3 guns	3 guns	3 guns	2 guns	6 guns
Indicated horsepower demand	5.68	7.29	8.24	4.63	12.01	8.48	9.36	7.21	3.17	4.1
Power factor of load, per cent	80.0	81.5	80.7	74.0	54.1	80.9	80.9	79.3	74.8	34.0

* Heavy voltage drop due to long low voltage leads.

† Using a 35-hp. irrigation motor.

‡ Starter grounded in tests 4 and 6 but not in 10.

§ General utility motor, system planned for 150 acres.

‖ L. S. means lime sulfur, A. of L. means arsenate of lead.

FIELD TESTS

The object of the tests was to determine the mechanical features and characteristics of the systems in use and to coöperate with owners and manufacturers with the purpose of suggesting improvements.

Points Investigated.—The following points were investigated:

1. Voltage at the motor and line drop.
2. Power required.
3. Power factor.
4. Speed of motor and pump.
5. Accuracy of pressure gauges.
6. Pressure drop in pipe lines and hose.
7. Exact pressure at nozzles.
8. Quantity discharged at nozzles.
9. Uniformity of spray liquid.
10. Time required for spraying.

Procedure.—Wattmeters, voltmeters, and ammeters were connected into the circuit ahead of the starting switch, in order to obtain the electrical characteristics of each phase. When the plant was in regular operation, readings were taken of voltage, power, current, motor speed, pump speed, and pump pressure. The pressure gauges were calibrated by comparison with a test gauge. The field observations consisted of reading the pressures at risers and nozzles, measuring the quantity of discharge, and taking samples of the spray.

Discussion of Results.—The voltage drop is dependent upon the distance from the transformer to the motor, the size of the wire, and the power demand on the motor. The importance of short lines and large wires is illustrated by the two following cases: With a 7.5 horsepower motor, 2500 feet from the transformer, connected by No. 8 wire, on a 220-volt circuit, there was found to be a drop of 35 volts; while with a 35-horsepower motor, 50 feet from the transformer, and connected with No. 6 wire on a 220-volt line the voltage drop was only 3 volts.

There was a rather wide range of power consumed, varying from 3.17 to 12.01 horsepower. The factors governing the power were the pressure maintained at the pump, the size and speed of the pump, and the efficiency of the plant. For highest efficiency, the motor should carry a full load and the pump should have a capacity little more than the combined requirement of the nozzles.

The power factor at the motor varies with the size of the motor, its load, and the power factor of the feeding circuit. This was found to range between 34 per cent for a 15 horsepower motor with one-quarter load and 81.5 per cent on a 7.5 horsepower motor with a full load (table 4). It is evident, therefore, that a motor should be chosen with the manufacturer's rating about equal to its load, in order that the power factor may be high. The efficiency of an induction motor running with a low power factor is low, and, therefore, is expensive to operate. A low power factor places an unnecessary burden on both the consumer and the power company.

The pump speeds ranged from 38 to 59 r.p.m., and the motor speeds from 840 to 1203 r.p.m. It was found that one pump was operating 15 r.p.m. above its rated speed because of the incorrect selection of pulleys.

The pressure gauges in every test were found to be inaccurate, in some cases the error was as high as 50 pounds to the square inch. Water-logged air chambers were a common occurrence and were undoubtedly responsible for damaged gauges.

The friction drop depends upon the size and length of the main and laterals in operation, the condition of the inside of the pipe, the character of fittings and turns, the kind of liquid, and the rate of flow (table 2). A small pressure drop can be obtained by the use of large pipe. However, if too large pipe is used, the velocity will be so low as to permit settling out of heavy chemicals in suspension, a condition which may result in uneven concentrations being applied to the trees. The orchards tested showed no such trouble with present installations. Samples of spray liquid collected from the nozzles in the several orchards showed practically the same concentrations at various points. The tests showed that 1 to 1½-inch mains and ¾ to 1-inch laterals give the best practical results. In one orchard which had a 1-inch main 1100 feet long, and ¾-inch lateral 200 feet long, the pressure drop from pump to nozzle was 115 pounds, when three spray guns were in operation. This excessive loss in pressure may be decreased by two methods: first by increasing the size of the main, and second by decreasing the number of nozzles per lateral.

In order to determine the relation between pressure drop and the number of nozzles in operation, several tests were run at two orchards. A pressure gauge was inserted directly back of the nozzle and readings were taken while neighboring nozzles were alternately opened and closed.

In one test two nozzles were operating on 862 feet of $1\frac{1}{2}$-inch main and 1460 feet of $\frac{3}{4}$-inch lateral. Nozzles on other laterals were in operation while the following readings were taken:

Average pump pressure	Nozzle No. 1	Nozzle No. 2	Pressure at No. 1
Lbs. per sq. in.			*Lbs. per sq. in.*
200	Open	Open	140
200	Closed	Open	170
200	Closed	Closed	180

In the second orchard, the pressure readings were taken with three nozzles in operation. The main was 960 feet of 1-inch pipe and the lateral 1080 feet of $\frac{3}{4}$-inch pipe to riser No. 1, 1160 feet to riser No. 2, and 1240 feet to riser No. 3. The following readings were taken:

Pump pressure	Nozzle No. 1	Nozzle No. 2	Nozzle No. 3	Pressure at No. 1	Pressure at No. 2	Pressure at No. 3
Lbs. per sq. in.				*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
410–20	Open	Open	Open	187	172	165
410–20	Closed	Open	Open	....	236	225
410–20	Closed	Closed	Open	....	337	295

In this same test pressure gauges were inserted between the service cock and the hose. These results are only indicative because the condition of the hose and disks is constantly changing. The following show the readings of the gauges with 115 feet of $\frac{7}{16}$-inch hose:

Riser pressure	Pressure			Pressure drop in hose		
	Nozzle No. 1	Nozzle No. 2	Nozzle No. 3	No. 1	No. 2	No. 3
Lbs. per sq. in.	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs.*	*Lbs.*	*Lbs.*
192	....	172	165	....	20	27
197	....	....	170	....	....	27
202	187	....	....	15	....	....
206	192	....	....	14	....	....
261	....	236	225	....	25	36
335	....	....	295	....	....	40

Table 5 has been made from data given in questionnaires filled out by the owners and from data in previous tables, to show the acreage covered, number of trees sprayed, and the amount of spray applied.

TABLE 5

RESULTS OF COMPUTATIONS ON RATE OF SPRAYING

Test group	A	B	C	D	E	F
Total gallons of spray	71,756	No data	23,200	17,400	13,200	....
Acres sprayed	260		55	42	31	30
Number of nozzles in operation*	13r		5g	3g	2g	6g
Total number of men employed	30		8	6	3	8
Total number of trees	20,200		3,500	4,524	3,320	2,250
Trees to the acre	77.7		63.6	107.7	107.2	75
Hours to spray	61.5		33	33	47	10.8
Acres sprayed per hour	4.23		1.67	1.274	.66	2.78
Trees sprayed per hour	328.5		106.2	137.2	70.6	208.2
Gallons per nozzle per hour	89.7		140.6	176.0	140.5	....
Acres sprayed per nozzle per hour	.325		.333	.425	.3295	.463
Trees sprayed per nozzle per hour	25.3		21.22	45.7	35.3	34.7
Gallons per tree	3.55		6.62	3.85	3.98	....

* r represents rods; g represents guns.

COSTS

Installation costs supplied by the owners ranged between $29.21 and $106.19 an acre. The latter figure is exceptionally high because the cost of rebuilding the plant after its destruction by fire was included. A fair average seems to be $37.50 an acre, as represented by "D" in table 6. Operating costs for a single application varied from $5.04 to $12.69 an acre, or .7 to 3.7 cents per gallon of spray. This cost depends upon the kind of spray used, the amount per tree, the rate of application, and the efficiency of the plant. These figures include all labor, material, power and repairs.

SUMMARY AND CONCLUSIONS

A stationary spray system consists of a central pumping station and pipe lines laid systematically throughout the orchard, with outlets at regular intervals, to which hose are attached for spraying the trees.

The first stationary spray plant was used by Hayward Reed, in 1908. There are today about a dozen such systems in California,

TABLE 6

COST OF INSTALLATION AND UPKEEP.

COST OF INSTALLATION (Owners' figures)

Test group	A	B	C	D	E	F
Total first cost	$15000.00	$10000.00	$6000.00	$1875.00	$1110.00	$1560.00
Total acres piped	260	250	56½	50	38	30
Total trees under pipe	20,200	22,000	4300	5000	4350	2250
Installation cost per acre	$57.69	$40.00	$106.19	$37.50	$29.21	$52.00
Installation cost per tree	$.743	$.454	$1.395	$.375	$.255	$.693

NOTE: Group "C" is high due to irrigation motor cost and fire repairs.
Group "D" is a fair example of what cost should be.

OPERATING COSTS (Single spraying)

Test group	A	B	C	D	E	F
Acres sprayed	260	No data	55	42	31	No data
Trees sprayed	20200		3500	4524	3320	
Gallons of spray	89820		42000	17400	13200	
Labor cost	$1661.81		$99.45	$68.00	$80.00	
Power cost	$23.00*		$7.92*	$12.80	$2.64	
Material cost	$1613.76		$166.75	$376.27	$190.00	
Repairs	....		$3.20	$2.25	....	
Total operating cost	$3298.57		$277.32	$459.32	$272.64	
Operating cost per acre	$12.687		$5.042	$10.936	$7.175	
Operating cost per tree	$.163		$.079	$.101	$.063	
Operating cost per gallon	$.0367		$.0066	$.0264	$.0208	

* Estimated.

FIXED CHARGES (Based on system life of 15 years)

Test group	A	B	C	D	E	F
Depreciation per year (6.66%)	$1000.00	$666.67	$400.00	$125.00	$74.00	$104.00
Interest (6%)	900.00	600.00	360.00	112.50	66.60	93.60
Taxes	....	....	....	....	....	....
Insurance	....	....	....	....	....	....
Total	$1900.00	$1266.67	$760.00	$237.50	$140.60	$197.60
Charge per acre	7.31	5.06	13.46	4.75	3.70	6.58
Charge per acre single spraying (based on 5 sprays a year)	1.46	1.01	2.69	0.95	.74	1.32
Operating cost per acre single spraying	12.69	No data	5.04	10.94	7.175	No data
Total cost per acre single spraying	$14.15	....	$7.73	$11.89	$7.915	....

the orchards ranging in size from 19 to 260 acres, while in the state of Washington there are several hundred plants in orchards from 3 to 160 acres in size.

The advantages of stationary spray plants are many, but the principal ones are that spraying may be done on time in spite of adverse soil or weather conditions and that pests requiring quick action may be speedily controlled. Thorough spraying may be accomplished with a saving of labor and time, with a low operating cost and low fixed charge. Other advantages are:

a. It is possible to irrigate and spray at the same time.

b. Spraying is possible with a minimum danger of knocking off or bruising the fruit on low hanging branches.

c. Props offer little interference to spraying.

d. Hillside orchards may be sprayed easily.

e. Intercrops or permanent cover crops are not injured, since tractors and teams are not required.

f. Men are separated so that they do not spray each other.

g. Electric energy may be used, which is more convenient than gasoline power.

h. Ninety-five per cent of the time is used in spraying and no time is lost in refilling.

i. The system is a permanent improvement to the property.

The disadvantages are:

a. Initial cost is high. This is not a great disadvantage, however, considering the long life of the installation.

b. All dependence is placed in one plant.

c. The system is limited to the extent of the pipe lines.

d. There is some possibility of materials settling in the pipes. With mains of proper size and with sufficient nozzles in operation to maintain velocity, this difficulty becomes negligible.

e. There is a possibility of damage to the system during cultivation, especially when subsoiling.

f. There may be corrosion of the pipes and fittings. Proper flushing after each spraying minimizes this difficulty.

g. Some spray material is wasted during flushing.

h. There is loss of pressure due to friction in long pipes and hose, thus necessitating high pump pressures.

There is a possibility of combining the advantages of the portable sprayer and the stationary spray plant by piping sections of the orchard that would be benefited and using the portable sprayer for

supply and power. In other words, the portable rig becomes the pumping station for the permanent piping system and at other times is available for spraying parts of the orchard where there is no pipe line. Some growers are actually using this combination to good advantage. Other growers lay the piping system on top of the ground, but this method is suggested only as a temporary measure.

ACKNOWLEDGMENTS

The writers desire to express their appreciation to Professor L. J. Fletcher, who was largely responsible for starting this investigation. Grateful acknowledgment is due to Dr. W. L. Howard for his careful reading and revision of the manuscript. Thanks are also due to Professor W. P. Tufts and Mr. F. A. Hanson for their suggestions and assistance during this investigation.

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